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APPLICATIONS OF DIGITAL DISPLAYS IN PHOTOINTERPRETATION AND DIGITAL MAPPING

by

BRYCE L. SCHROCK

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The Digital Image Analysis Laboratory (DIAL) at USAETL is a large-scale interactive system designed for research and development activities in digital image processing. The system has been successfully applied to a variety of investigations in both digital mapping and photointerpretation as described in this presentation. Recently a Demonstation Image Processing System (DEMONS) has been added to the DIAL system to serve as a high-speed work station for processing very large digital images. Although DEMONS has been reasonably successful in manipulating large images, its limitations indicate that future such systems might

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APPLICATIONS OF DIGITAL DISPLAYS IN PHOTOINTERPRETATION AND DIGITAL MAPPING

Bryce L. Schrock
Computer Sciences Laboratory
U.S. Army Engineer Topographic Laboratories
Fort Belvoir, Virginia 22060

BIOGRAPHICAL SKETCH

Bryce L. Schrock received his B.S. from Purdue University and his M.S. and PH.D. in experimental high energy physics from the University of California at Los Angeles. He has been a research associate at UCLA, a research scientist at Battelle Memorial Institute, a senior member of the technical staff at Computer Sciences Corporation, and a consultant for the Rand Corporation. He began working as a physical scientist for the U.S. Army Engineer Topographic Laboratories (USAETL) in 1974. His work at USAETL has been primarily in the area of digital image processing, and he has been responsible for the design and implementation of a large-scale interactive image processing system. He received the Commander's Award for Scientific and Technological Achievement in 1976 and a Department of the Army Research and Development Achievement Award in 1977.

ABSTRACT

The Digital Image Analysis Laboratory (DIAL) at USAETL is a large-scale interactive system designed for research and development activities in digital image processing. The system has been successfully applied to a variety of investigations in both digital mapping and photointerpretation as described in this presentation. Recently a Demonstration Image Processing System (DEMONS) has been added to the DIAL system to serve as a high-speed work station for processing very large digital images. Although DEMONS has been reasonably successful in manipulating large images, its limitations indicate that future such systems might be hybrid systems combining the best features of both hardcopy (film) and softcopy (cathode ray tube) exploitation systems.

THE DIAL SYSTEM

The Digital Image Analysis Laboratory (DIAL) was assembled at USAETL in 1976 to serve as a testbed for research and development activities in interactive digital image processing. The system was jointly funded by the Defense Mapping Agency (DMA), the Army Space Projects Office (ASPO), and the Office of the Chief of Engineers (OCE). Since the system is a testbed, it has to be both flexible and expandable and, in addition, has to be reasonably efficient in manipulating the large quantities of data inherent in digital image processing. The system consists of hardware and software components each of which is described below.

DIAL System Hardware

The DIAL system hardware is basically composed of four

SCHROCK

major subsystems as depicted in Figure 1: (1) a CDC 6400 computer system, (2) a Goodyear STARAN parallel processing system, (3) an image display system, and (4) a DEMONStration image processing System (DEMONS). All four subsystems are interconnected by Digital Equipment Corporation (DEC) DRHCD channel couplers. These channel couplers have a hardware channel transfer rate of approximately four megabits per second and an effective data transfer rate of approximately two megabits per second. The CDC 6400 is the primary processor and control unit in the system, the STARAN is a high-speed processor used for computationally bound tasks, the image display system is the interactive portion of the system, and DEMONS is the high-speed work station for processing and display of extremely large digital images.

The CDC 6400 is a rather standard sequential processor with 131K 60-bit words of central memory (K=1024) and 250K 60-bit words of Extended Core Storage (ECS). In addition, the CDC 6400 system includes standard peripherals such as eight disk drives, four 7-track magnetic tape units, two 9-track tape units, and the usual card reader, line printer, and card punch.

The STARAN associative array processor is controlled by a DEC PDP-11/20 and contains four 256- by 256-bit arrays with each array possessing 256 elementary processing elements. Thus, unlike sequential processors which can perform only one operation at a time, the STARAN can perform 1,024 operations simultaneously. This parallel capability allows the STARAN to complete many calculations at a rate 50 to 60 times faster than the CDC 6400.

The image display system consists of a DEC PDP-11/50 controlling two independent work stations. Each work station is composed of a Tektronix 4014-1 alphanumeric terminal, an XY digital tablet, and two COMTAL 8300-SE image displays. Each COMTAL image display has a high-resolution color monitor and refresh memory for three 512- by 512-bit image planes and four 512- by 512-bit graphics planes. The image displays also contain the usual look-up tables for gray-level operations and pseudocolor tables for color operations. In addition, two of the four displays have real-time convolution and image combination processors. The PDP-11/50 controlling the two work stations acts as a slave to the CDC 6400 in that it responds to commands issued from programs executed in the CDC 6400.

The DEMONS system consists of a DEC PDP-11/70, two AMPEX high-density tape units, some special electronic processors, and a COMTAL S-200 display system. The high-density tape units write 28 tracks of information on one-inch wide tape at a packing density of approximately 30 kilobits per inch per track. The tapes record data at 33 megabits per second and playback the recorded data at 66 megabits per second and are used for storage of very large digital images. The special electronic processors perform a dynamic range compression of the recorded imagery data via a look up table and also perform spatial averaging and extraction on the large images in order to create a viewable image on the

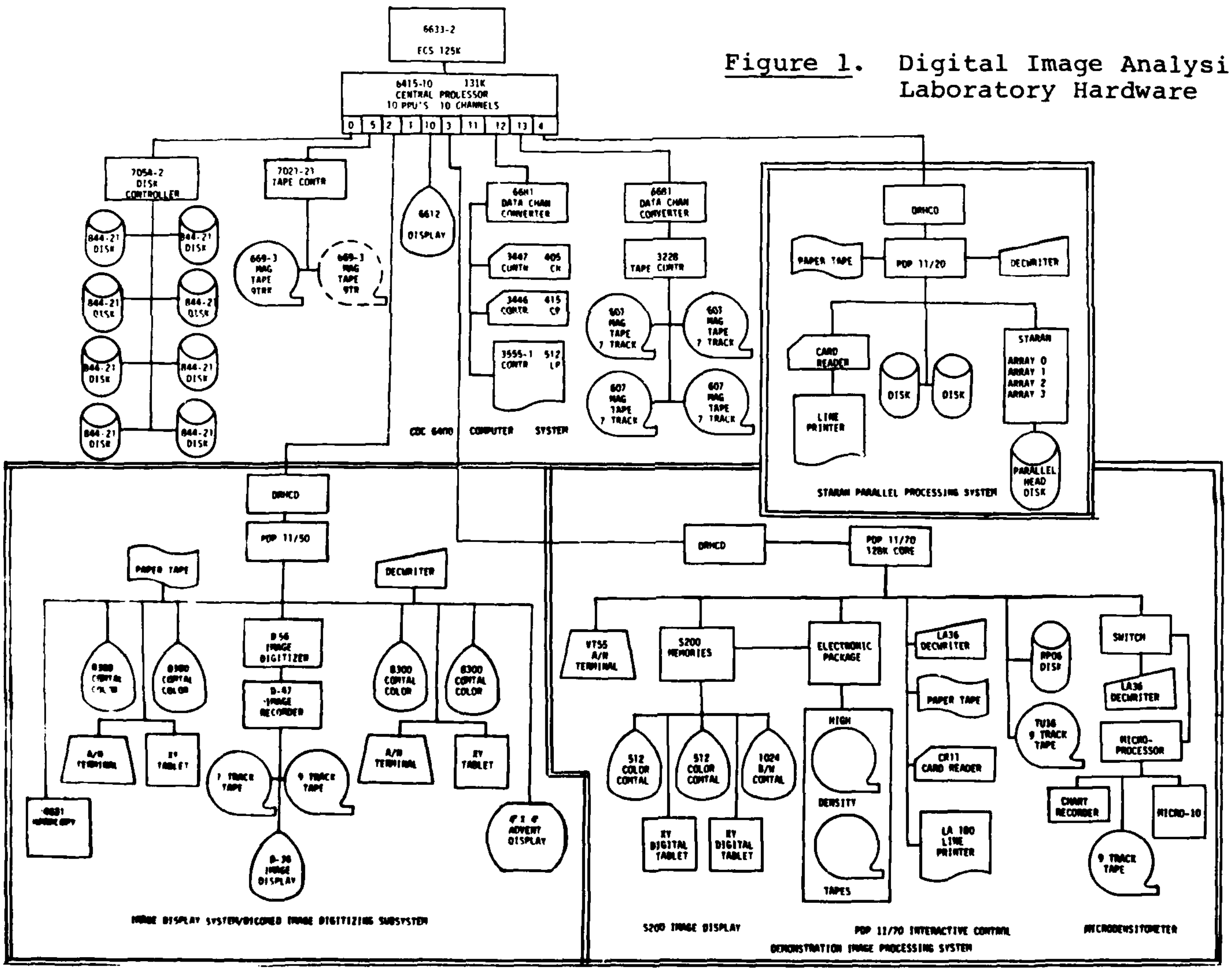

Figure 1. Digital Image Analysis Laboratory Hardware

COMTAL S-200 display system. The COMTAL S-200 consists of two 512x512 color monitors, one 1Kx1K black and white monitor, as well as approximately 50 million bits of refresh memory. It also contains several special processors to be described later in this paper.

DIAL System Software

The system software for DIAL was designed so that FORTRAN programmers could, with little effort, incorporate their own program modules into the system. This is made possible by a powerful set of FORTRAN interface routines which allows an executing FORTRAN program to explicitly control all interactive devices attached to the program. The FORTRAN interface routines also provide a simple but comprehensive data management capability so that bookkeeping chores are kept to a minimum for digital image programmers. In addition, this data management subsystem is based on a private disk pack philosophy resulting in several desirable features: (1) essentially unlimited mass storage space is available off-line and the stored data can be made available on-line within minutes, (2) a high degree of security is possible because classified data can be brought on-line only when needed and can be kept locked up at other times, and (3) management of mass storage space is left to individual groups rather than to the system manager.

Another important feature of the system software is that it allows application programs to be so written that they can process imagery data with anywhere from 1 to 48 bits per picture element (pixel). This feature is particularly important since the DIAL system has been utilized to investigate a variety of sensors, all with different dynamic ranges. In summary, the system software has proven to be so versatile and easy to use that well over 500 application programs have been implemented on the DIAL system.

DIGITAL MAPPING APPLICATIONS

Much effort has been expended on DIAL investigating those functions that might be included in future digital mapping systems. These investigations can be categorized into the following topics: (1) stereocompilation, (2) digital mapping products, and (3) feature extraction. Each of these topics is briefly described below.

Stereocompilation

Stereocompilation can be broadly defined as the extraction or calculation of elevation values from stereo photographs or images. In a digital system, the calculation is accomplished by extracting a small patch of pixels, e.g., 9x9 pixels, from one mate of the stereo pair and then locating the corresponding patch, using correlation techniques, on the other mate. Several techniques and parameters involved in this process have been investigated on the DIAL system. These investigations have included trying different measures of correlation, varying the size of the extracted patch, and shaping the patch according to terrain values already calculated. The results of these studies are described by Crombie (1975, 1976).

There are two advantages in performing the stereocompilation on an interactive digital system: (1) the results of the compilation process can be viewed and edited at the same time that the compilation is being performed, and (2) the resulting matrix of elevation values is in perfect registration with one of the stereomates used to calculate the matrix, i.e., the elevation is known for each point on the ground truth image. This latter advantage greatly simplifies the creation of digital mapping products which might be desired from the model area.

Interactive editing of the stereocompilation results is also currently being studied on the system. Editing is required since the compilation process occasionally loses correlation and consequently produces erroneous elevations. The first step in the editing process is to view, on the CRTs, the results of the compilation process. This can be accomplished in several ways. One technique is to produce a shaded relief map by defining the position of the sun relative to the elevation matrix and then letting the computer calculate the shaded areas. Erroneous elevation values are then often very obvious on the displayed relief map. Another technique is to superimpose calculated elevation profiles on a three-dimensional presentation of the stereo imagery using an anaglyphic technique. Viewed in stereo, elevation profiles which do not lie on the ground are then a clear indicator of erroneous elevation values.

The next step in the editing process is to interactively correct the erroneous elevation values. Again this can be accomplished in several ways. One technique allows the operator to force a floating dot to lie on the ground along those profiles which are obviously incorrect, i.e., those profiles which do not already lie on the ground. The newly defined profile then replaces the erroneous data in the elevation matrix. A second technique allows the operator to use a floating dot to trace a contour line which is constrained to a specified elevation. The resulting operator-generated contours can then again be used to calculate elevation values to replace erroneous data in the original matrix. The compiled and edited elevation matrix is then available for use in creating the digital mapping products described below.

Digital Mapping Products

A large number of interesting products become possible when digital ground truth imagery and corresponding registered elevation matrices are available. The following products, implemented on DIAL, are merely a few of the many possibilities. For example, contour lines can be superimposed onto the ground truth image itself and the result displayed on a CRT. The Image Analyst (IA) then has simultaneously available to him ground truth information from the photograph and terrain information from the contour lines. The IA can also move a cursor to any point on the displayed ground truth image and instantaneously be notified, via the

CRT, about the elevation at that point; or the IA can use the cursor to select two points on the ground truth image and the computer can then draw the elevation profile between the two selected points on the CRT. This sort of function is useful for antenna placement problems, observation post location problems, etc. In a similar fashion, the location of a radar site can be specified on the ground truth image. The computer can then calculate what areas in the image are visible to the radar in a line-of-sight sense. This visibility plot can be presented to the IA on the CRT by displaying an overlay which covers up all areas on the ground which are not visible to the radar. This sort of function is useful for optimum placement of our own radars to cover known access routes or for evading known enemy radar locations.

Elevation data can also be useful for civil engineering applications. For example, cut and fill problems are very easily handled on an interactive system. An image analyst can specify any irregular area on the ground truth image and the computer can calculate, within a few seconds, the quantity of earth to be filled in or removed. This sort of function is applicable to road, railroad, or airfield construction and to reservoir planning projects.

Another interesting use for this type of data is the capability to view the model area from any vantage point given the fact that both ground truth imagery and registered elevation values are available. On DIAL, this is done by interactively specifying a viewing position and angle of observation. The computer can then calculate an oblique or perspective view and present the result on the CRT. This kind of presentation is useful for familiarizing troops with new terrain and for creating simulated flight paths over the model area.

In summary, there are many useful products which result from having ground truth imagery and corresponding elevation matrices. The few examples described above are only a small sample of the new and exciting products one can expect from a digital mapping system.

Feature Extraction

Feature extraction, as used in this paper, is the detection and classification of lineal and areal features on a photograph for the purpose of producing that abstraction which we call a map. It is one of the most important, but also most difficult to achieve, functions of a digital mapping system. Feature extraction research on DIAL has involved investigations in two areas: (1) development of multispectral classification capabilities, and (2) development of techniques to interactively extract lineal features from images.

Multispectral classification capabilities currently implemented on DIAL include a supervised classification scheme, based on the maximum likelihood method, and an unsupervised clustering scheme. For supervised classification, the operator is allowed to interactively define training fields in the image whereas for the unsupervised classification the image statistics themselves are used to define classes (clusters). In either case, the results of the classification process are used to produce pseudocolor-coded maps which are then displayed on the CRTs. A full description of these capabilities is available in the report by Rice et al (1978). Currently ongoing work on DIAL in multispectral classification involves using the STARAN parallel processor to perform many of the functions now performed on the CDC 6400. It is estimated that the time to classify an entire LANDSAT scene can be reduced from 386 minutes to 10 minutes if the STARAN is used. Other work involves implementation of the Karhunen-Loeve transformation to reduce a multispectral image to its principal components thus reducing the amount of redundancy in the imagery to be classified.

Extraction of lineal features such as roads, railroads, and streams from images is obviously an important part of making a map. Techniques investigated to date have followed the approach described by Fischler et al (1979). Basically, the image from which the extraction is to occur is presented on the CRT to an image analyst who then selects several guide points on the lineal feature to be extracted The computer then attempts to perform the extraction by optimizing a global figure of merit utilizing all available information about the feature to be extracted. The computer's result is then displayed for the analyst who can correct any errors the computer might have made.

The feature extraction investigations described above are merely the initial attempts to partially automate the process which in the past has relied almost totally on the superb pattern recognition abilities of the human analyst.

PHOTOINTERPRETATION APPLICATIONS

The first application of the DIAL system was to the task of photointerpretation and consequently the very large number of functions which have been implemented permits only a cursory description of these operations. The primary areas of research include dynamic range adjustments, geometric operations, filtering operations, and search and detection operations. Each of these topics is briefly discussed below. In addition, the system has been used for a series of photointerpretation experiments, the results of which are summarized.

Dynamic Range Adjustments

If the dynamic range of an image can be contained in 8 bits per sample or less, then the presentation of that dynamic range on the CRTs can be changed instantaneously by using the look-up tables which exist in the display systems. This capability has been fully exploited in DIAL by software coupling the look-up tables to an interactive device which is under the control of the interpreter. The resulting capability of the interpreter to instantly change imagery contrast, look into shadows, etc., has proven to be one of the most powerful tools of an interactive digital system.

If the dynamic range of an image is more than 8 bits per sample, then the full information content of that image cannot be recorded on film but can be retained and exploited in a digital system. A variety of dynamic range adjustments such as log compression, exponential compression, and linear mapping have been investigated in order to make the full dynamic range of these images available to the interpreter.

<u>Geometric Operations</u>

A digital image can be geometrically altered according to any desired model and this capability exists in the DIAL system. The major applications which require this capability include: (1) change detection, (2) rectification of non-orthogonal images to produce orthophotos, and (3) the registration of images from different sensors to allow multisensor fusion. This latter capability, multisensor fusion, has proven to be particularly useful to radar interpreters who use optical images to aid in the radar interpretation process.

<u>Filtering Operations</u>

Filtering operations on DIAL can be performed in either the spatial domain or the frequency domain. The Fast Fourier Transform (FFT) is implemented in software and thus about 90 seconds are required to create the transform of a 512x512 image. Spatial convolutions can be performed on 512x512 images either in real time for 3x3 kernels or in less than 5 seconds for kernels as large as 15x15. Filtering operations on DIAL have been used to sharpen imagery, remove degradations, and to evaluate various compression techniques.

<u>Photointerpretation Experiments</u>

A series of experiments have been conducted on DIAL to determine the utility and value of softcopy (CRT) exploitation as compared to hardcopy (film) exploitation for tactical imagery. Results from these experiments have shown that: (1) softcopy interpretability is superior to hardcopy and (2) the degree of superiority increases as the quality of the imagery decreases. In addition, the experiments have demonstrated that photointerpreters have little difficulty in transitioning from a hardcopy to a softcopy environment and in fact greatly prefer the latter.

<u>Search and Detection Operations</u>

Searching for and detecting targets in very large digital images is an operation which is inordinately difficult to implement in softcopy systems. The reasons for this difficulty are the following: (1) large images are represented by a very large quantity of data which must be stored, moved around, and processed at rapid rates and (2) digital CRTs can display, at full resolution, only a small fraction of a truly large digital image, i.e., the displays are much smaller, pixel wise, than the images. These difficulties have been investigated on the DIAL system for images less than 4Kx4K pixels in size. In general, the approach has been to use two CRTs for the search problem: (1) the first CRT displays a reduced resolution overview of the image being searched and this overview is used as a "road map" to guide the interpreter in the search process and (2) the second CRT displays, at full resolution, small portions of the entire image which have been selected by the interpreter for more intensive analysis. This procedure works reasonably well for images of size 4Kx4K pixels or smaller. However, most images of use to tactical interpreters and to the mapping community are far larger than 4Kx4K. In order to determine whether or not very large images could be handled in a softcopy system, the DEMONS system was assembled. That system is described below.

DEMONSTRATION SYSTEM (DEMONS)

The DEMONS System was created in order to demonstrate the feasibility of performing, in a purely softcopy environment, tactical interpretation of extremely large digital images (images well in excess of 10K x 10K pixels in size). The DEMONS hardware has already been briefly described in this paper but a more detailed description of the COMTAL S200 is necessary in order to understand how the entire system operates.

The COMTAL S200 is designed to exploit images 2K x 2K x 8 bits in size. In order to accomplish this exploitation, the S200 includes two 512 x 512 color monitors, a 1K x 1K black and white monitor, several refresh memories, and some special processors. The more important refresh memories, all 8 bits deep, include a 2K x 2K data base memory, a 1K x 1K overview memory, two 512 x 512 local memories, and one 512 x 512 fast access memory. The more important processors provide the capabilities: (1) to reduce the resolution of the 2K x 2K data base memory by averaging and to load the result into the 1K x 1K overview memory, (2) to "roam" around the data base memory, i.e., to present, under operator control, any 512 x 512 portion of the data base memory on a 512 x 512 color monitor, and (3) to "zoom" imagery residing in the fast access memory, i.e., to instantaneously and smoothly magnify, by any scale factor and by cubic convolution resampling, imagery residing in that memory. The S200 also includes the usual look-up tables to provide gray-level mapping and pseudocolor operations. These hardware features of the S200, in combination with the high-density tapes and their associated processors, permit a two-phase exploitation of the very large digital images.

The first phase of the exploitation process proceeds by reading the entire image from the high-density tapes, at 33 or 66 megabits per second, performing a dynamic range compression to reduce the number of bits per pixel to 8, and performing spatial averaging to reduce the resolution and size of the entire image. This process, requiring

100 or 50 seconds depending on the tape speed, results in a 2K x 2K x 8 bit image which is loaded into the S200 data base memory. The entire image is further reduced in resolution by a factor of two, loaded into the overview memory, and presented for viewing on the 1K x 1K black and white monitor. The operator then uses this overview image in conjunction with the roam, zoom, and gray-level mapping capabilities of the S200 to select areas he wishes to view at full resolution in the second phase of the exploitation process.

The second phase of the process proceeds in much the same manner as the first except in this case full-resolution 2K x 2K portions of the entire image are extracted and loaded into the S200 data base memory. In addition, in this phase, the interpreter is given the ability to perform targeting and mensuration operations on the full-resolution imagery. This two-phase process continues until the entire large image has been exploited.

Although DEMONS was reasonably successful in manipulating very large images, several limitations became apparent during operational use of the system: (1) unduly long response times were experienced by having to reposition and read data from the high-density tapes, and (2) the image overview produced in the first phase of the exploitation process was, in many cases, of insufficient resolution to serve as an adequate "road map" in guiding the search process. The first limitation could be overcome to a large degree by incorporating parallel transfer disks into the DEMONS system. In this case, the image to be exploited would be loaded from the high-density tapes onto the parallel transfer disks and all subsequent exploitation would occur using data from the disks thus greatly reducing the time required to extract any portion of the entire image. Note that this solution retains the purely softcopy nature of the system. The second limitation, the overview problem, is considerably more difficult to overcome in a totally softcopy environment. This consideration has led to speculation about the value and possibility of hybrid solutions combining the best features of hardcopy and softcopy systems.

FUTURE HYBRID SYSTEMS

Although DEMONS was created for the task of photointerpretation, the same limitations as described above would be encountered in a digital mapping system which attempted to exploit large digital images. And, of course, the problems become much worse if such softcopy systems are required to handle several sensor inputs simultaneously. Another consideration is the fact that softcopy systems can become quite expensive and much of this expense results from trying to handle the overview and "search and detection" problems. Given these facts, it appears prudent to consider hybrid systems which utilize film, or other hardcopy media, in conjunction with proven softcopy techniques.

To reduce such speculation to concrete concepts, the following hypothetical requirement is useful. An exploitation station is required to receive, and exploit simultaneously, the inputs from two digital sensors. Given such a requirement, a hybrid exploitation station might assume the following form. Imagery data would be received and written on high-density tapes with associated parallel transfer disks. Simultaneous with reception, the imagery would be sent to, for example, a laser beam recorder to produce a film, or other hardcopy, rendition of the imagery. The hardcopy images would be placed on two small light tables equipped with simple optics and digital XY coordinate sensors on each table. The image analyst would then use the hardcopy renditions of the images both as overviews and as the proper media on which to perform search and detection operations. Whenever the interpreter located an area to be more fully exploited on either or both images, he would use the XY coordinate sensors to specify that area to the softcopy portion of the system. The designated area(s) would then be extracted from the digital data and loaded into 1K x 1K refresh memories for viewing on 1K x 1K black and white monitors. A third monitor would also be available to support operations such as magnification, gray-level mapping, filtering, feature extraction, sensor fusion, etc. Results of the exploitation process would be recorded digitally for future use.

A hybrid system, such as briefly described above, might possibly be a more cost-effective solution to the stated hypothetical requirement than either a purely hardcopy or softcopy system. Obviously, specification of optimal configurations for systems which must manipulate digital inputs from modern sensors is a task that requires considerable thought and experimentation in the near future.

SUMMARY

The DIAL System has proven to be an extraordinarily powerful and robust system for research and development activities in the application of digital image processing techniques to photointerpretation and digital mapping. The DEMONS System, although reasonably successful in manipulating large digital images, has several limitations which might be overcome by hybrid systems which combine the best features of both hardcopy and softcopy exploitation capabilities.

REFERENCES

1. Crombie, M.A., 1975, "Simiautomatic Passpoint Determination Using Digital Techniques," ETL Report -0051.

2. Crombie, M.A., 1976, "Stereo Analysis of a Specific Digital Model Sampled from Aerial Imagery," ETL Report - 0072.

3. Rice, W. C., Shipman, J.S., Spieler, R. J., 1978, "Interactive Digital Image Processing Investigation," ETL Report -0172.

Schreck

4. Fischler, M.A., Tenebaum, J.M., Wolf, H.C., 1979, "Detection of Roads and Linear Structures in Aerial Imagery by Computer," SRI International Technical Note 200.